High Depth Color Print Control Technology

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Electrophotographic printers are required to provide photograph quality printing with the rapid implementation of color in an office environment and meet the needs for POD[*1)]. The printing quality of conventional color electrophotographic printers is no longer capable of adequately satisfying the needs of customers. Furthermore, printing systems with a high resolution are used in the pre-press process for digital plate making systems that comprise a portion of offset printing processes, as the popularization of digital printing systems continues. Thus, a higher printing quality is required even in such markets.

The ProQ Multi-level technology is a high depth color control system developed to respond to such needs with a more reasonable price range. This system realized the reproduction of gradation at the engine level for the first time with electrophotographic printers, our core product competence, which use a high definition LED printheads as the light source.

This paper introduces a newly developed ProQ Multi-level technology, as well as related peripheral technologies.

Gradated expression system

General methods are described for expressing color depth, which is a basic subject for reproduction for image reproducing devices.

(1) Area gradation

It is possible to reproduce original image data with picture element data carrying multiple values even with printer engines that only have binary expression capabilities. Color depth is expressed by modulating the number of dots in a given area (area proportions) as shown in **Fig. 1** and is also known as area gradation or pseudo gradation.

(2) Continuous gradation

On the other hand there is something called continuous gradation, shown in **Fig. 2**, which is often mentioned with representative examples of silver films and dye sublimation printers. This is a method used to reproduce gradation in a continuous manner, using silver particles or dye particles and therefore, it is a method that can fundamentally provide shading in infinite levels and can be considered an application of chemical reactions in an analog manner.

A comparison of these systems indicates that area gradation requires a larger area to express the same amount of information relating to picture element data, whereas the amount of information for a given area is smaller, it offers a lower expressive capability.

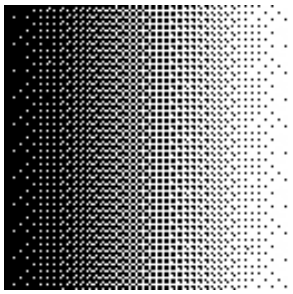

Fig. 1 Area gradation

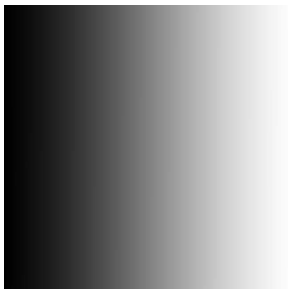

Fig. 2 Continuous gradation

Variable Dot Control system

A description of the newly developed ProQ Multi-level technology is provided below.

(1) Background of development

These days in order to respond to the needs for a higher printing quality, from the perspective of control systems for image reproduction, it was necessary to improve the basic performance to reproduce as much image information as possible in a small area. Applying a high resolution exposure device meant that not only are costs applied to the device itself, but costs also go up for peripheral systems that support such a device. This is detrimental to the other basic need for lowering the costs of electrophotographic printers.

Therefore, we selected to respond to this need, not by increasing the resolution by employing an exposure device, but rather by making the high definition LED printheads support high color depth expressions representing one picture element with a dot resembling continuous gradation. If this is realized then the basic capability of the image reproduction device improves making it clear that printing output with a higher quality can be obtained.

A targeted performance by the device suggested before development started was a 200-line screen resolution with 256-level of gradation, considered to be sufficient for printing the quality required for applications, such as the printing of full-color catalogs and calendars,

*1) Print On Demand

in general. By converting this into an engine performance, we have a device with a 1,200 dpi printhead and 16 gradation levels per picture element or a device with a 600 dpi printhead and 32 gradation levels per picture element.

(2) Exposure energy control

In order to achieve 32 levels of gradation for each element on a device with a 600 dpi printhead, it was necessary to improve the printer engine's energy control resolution capability, as printer engines previously only had binary expressions. It appeared, however, that it would be extremely difficult to find materials that could be used as a basis for deciding the extent of control resolution required. In order to overcome this problem, a process model was developed that is both detailed and practical and applies to the exposure process as well as the developing process by the high definition LED printheads. **Fig. 3** shows an optical image of the high definition LED printheads. **Fig. 4** shows an electrostatic latent image obtained by applying this optical data to the model and **Fig. 5** is a toner image resulting from the output of processing this electrostatic image by the model. **Fig. 6** shows a logical relationship between these process elements. Furthermore, this model reproduces printing for the entire gradation range and the development result is evaluated in terms of optical density, as shown in **Fig. 7**, which compares printing by the ProQ Multi-level technology with output from a conventional printer engine using area gradation. It was possible to realize gradated reproduction with a high degree of linearity using the ProQ Multi-level technology and this can be considered a result for discovering the optimum energy control resolution capability and faithfully incorporating it into a system. Furthermore, the crisp printing output, a characteristic of the high definition LED printheads, remains in good condition also with text printing using the ProQ Multi-level technology, as an output for the fine printing of characters as shown in **Figs. 8** and **9** (next page).

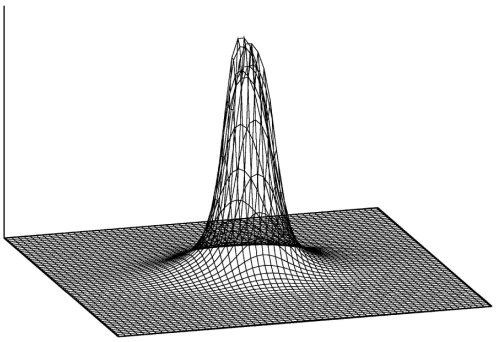

Fig. 3 Optical image of high definition LED printhead

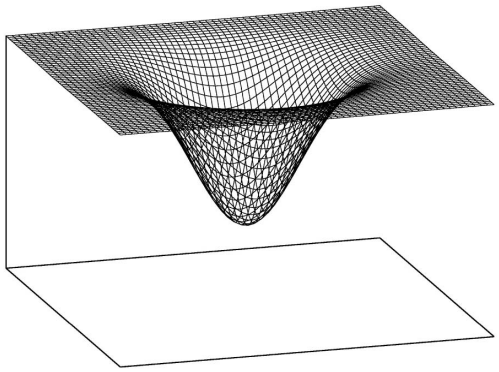

Fig. 4 Electrostatic latent image

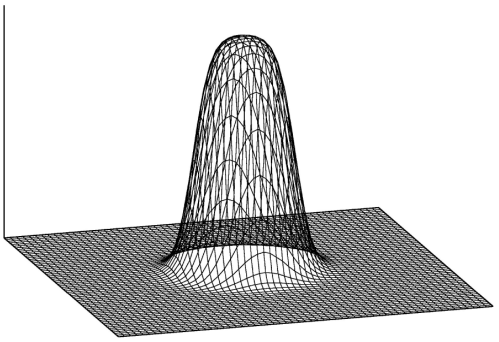

Fig. 5 Toner image

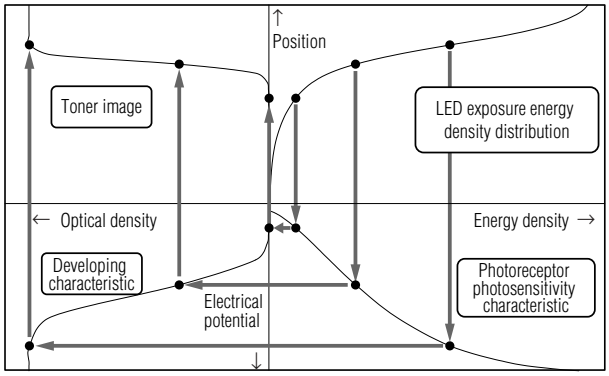

Fig. 6 Logic of process model

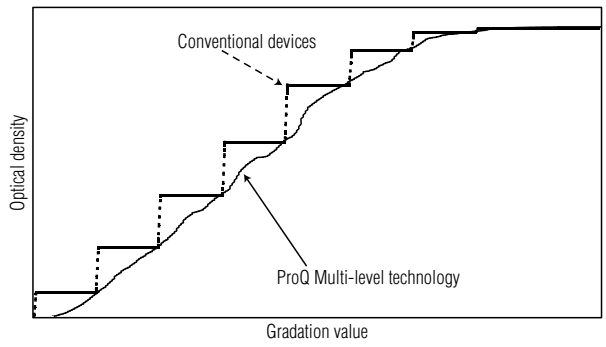

Fig. 7 Gradated expression using ProQ Multi-level technology

Fig. 8 Fine characters 1

Fig. 9 Fine characters 2

(3) Image information amount

As mentioned previously the ProQ Multi-level technology is used to improve the basic function of "reproducing as much image information as possible in an area as small as possible". This can be achieved by raising the resolution of the device, but even with a printer engine for a product with a resolution of 2,400 dpi, it is able to offer a mere 145-level of gradation with a 200-line screen when a binary-based area gradation is employed. On the other hand the resolution for the C9600 and C9800 series of devices are 600 and 1,200 dpi respectively, but the gradated reproducing capability with the application of the ProQ Multi-level technology reaches a maximum of 256-level of gradation with a 200-line screen, a quantity of image information approximately double that of 2,400 dpi devices.

Related peripheral technologies

Related technologies developed and applied to the product at the same time as the ProQ Multi-level technology, are introduced as technologies for providing peripheral support for the ProQ Multi-level technology.

(1) Exposure energy optimization control

Through utilization of the aforementioned process model, it was discovered that exposure energy spreads across picture elements and causes mutual interference due to the distribution of an exposure energy density, which in turn impacts greatly on the printing output. For this reason a technology was developed and used in conjunction with the ProQ Multi-level technology, to evaluate the extent of interference by the exposure energy and to optimally control the energy. Since an adequate density could not be obtained with conventional printers, particularly with those that use independent dots, in order to express the high-lighted portions of images, there really was no option but to sparsely arrange dots with a larger composition. This exposure energy optimizing control, however, makes it possible to reproduce images in a stable manner, even when gradation values are quite small, thereby contributing to an improved printing quality.

(2) Compensation of variation in optical characteristics

An optical system for high definition LED printheads uses a rod lens array. A rod lens array is comprised of several hundred micro-lenses arranged to fill the entire span of the main scanning direction. Any variation in the characteristics of these micro-lenses can cause a negative impact on printing. With conventional printer engines it was only necessary to use exposure energy in two patterns, on and off. It was, therefore, possible to statically compensate energy to adequately deal with such variations in characteristics[*1)]. With the ProQ Multi-level technology, however, not only is it necessary to perform this compensation to all of the many LED light sources, it is also necessary to dynamically optimize energy compensations on the exposure energy, for which high color depth control is conducted in response to the varying image data, with multiple values. This problem was resolved by processing data using a newly developed high-speed arithmetic circuit and by highly densely incorporating characteristic data obtained during the manufacturing process of high definition LED printheads .

Future agendas

The core of the ProQ Multi-level technology described in this paper is incorporated in a specifically developed LSI and loaded on our flagship models, the C9600 and C9800 series. We consider it our future agenda to continue optimizing the system and implement the technology into mid and low-end models by incorporating the rapidly evolving semiconductor technologies. Furthermore, by utilizing the extremely precise controlling capability of the ProQ Multi-level technology, we are hopeful that we will be able to obtain even finer color reproduction capabilities in the future.

Conclusion

This paper introduced the high depth color print control technology uniquely developed by Oki Data, the ProQ Multi-level technology and its related technologies as well as also indicating that the ProQ Multi-level technology is contributing greatly to the dramatically improved printing quality without triggering any rise in costs due to the increase in resolution.

Afterward

A scanned image of a full-color printing output, using the ProQ Multi-level technology in our C9600 and C9800 series of products, is shown in **Photo 1**. For the purpose of comparison the printing output using our conventional device is shown in **Photo 2**, whereas **Photo 3** shows an output of printing performed by a laser printer available from our competition. It is clear to see that the printing output using the ProQ Multi-level technology has the richest expressing capability out of all of these.

Finally, we would like to emphasize that the dramatic improvement in the printing quality achieved by the C9600 and C9800 series has not been realized solely by the development of the ProQ Multi-level technology, but through comprehensive efforts of the entire development organization at Oki Data, including the development of toner and developer, as well as various process elements.

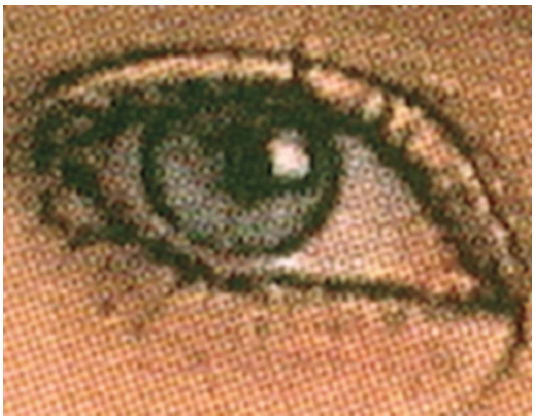

Photo 1 Printing output using ProQ Multi-level technology

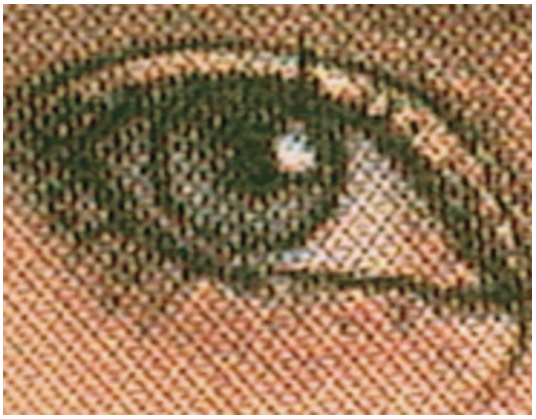

Photo 2 Printing output comparison with our conventional model

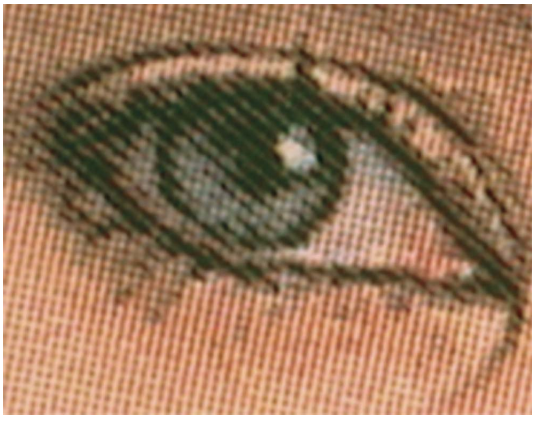

Photo 3 Printing output using a laser printer from our competition

References

1) Shigeki Nakajima et al: "Single Pass Color™ Printers Using Digital LED" Oki Technical Review, Issue 185 Vol. 68 No. 1, pp. 124-127, January 2001.

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